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CERTIFICATION

I, Yoshihiro Iwasaki c/o Murata Manufacturing Co., Ltd., at 26-10, Tenjin 2-chome Nagaokakyo-shi, Kyoto-fu, Japan,
do hereby certify that I am conversant with the English and Japanese languages, and I further certify that to the best of my knowledge and belief the attached English translation is a true and correct translation of the Japanese patent application No. 10-221533 filed on August 5, 1998.

Signed this on December 12, 2001

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[Title of the Invention] ELECTRONIC DEVICE AND METHOD FOR PRODUCING THE SAME

[Number of Claims] 4

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[List of Documents Attached]

[Name of Document]	Specification	1
[Name of Document]	Drawings	1
[Name of Document]	Abstract	1

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[Name of Document] SPECIFICATION

[Title of the Invention] ELECTRONIC DEVICE AND METHOD FOR PRODUCING THE SAME

[Claim]

[Claim 1] An electronic device in which a lower electrode layer comprising a material capable of reactive-ion etching with a fluorine-based gas is formed on a single crystalline base plate or single crystalline film, or on a triaxial or uniaxial orientation film, an upper electrode layer comprising a material capable of reactive-ion etching with a chlorine-based gas being formed on the lower electrode layer.

[Claim 2] A method for producing an electronic device in which a pattern is formed by etching a substrate film comprising a material capable of reactive-ion etching with a fluorine-based gas and formed on a single crystalline base plate or single crystalline film, or on triaxial orientation film or uniaxial orientation film, and a thin film comprising a material capable of reactive-ion etching with a chlorine-based gas, wherein

the thin film is etched by a reactive ion etching with a gas containing the chlorine-based gas, followed by etching the substrate film exposed from this thin film by a reactive ion etching with a gas containing the fluorine-based gas.

[Claim 3] A method for producing an electronic device according to Claim 2, wherein the substrate film contains at least one element among Si, Mo, W, B, C, S and Ta.

[Claim 4] A method for producing an electronic device according to Claim 2 or Claim 3, wherein the film thickness of the substrate film is 0.5 nm to 1000 nm.

[Detailed Description of the Invention]

[0001]

[Industrial Field of the Invention]

The present invention relates to an electronic device and a method for producing the same. In more detail, the present invention relates to an electronic device such as a semiconductor integrated circuit, a semiconductor device or a surface acoustic wave (SAW) device, and a method for producing the same.

[0002]

[Description of the Related Art]

When a reactive-ion etching (RIE) is applied to an aluminum alloy electrode film **2** formed on a single crystalline base plate **1** for use in surface acoustic wave devices, the surface of the electrode film **2** is covered with a photoresist **3** to mask the patterned photoresist **3** as shown in FIG. 1, followed by a selective etching using a chlorine-based gas such as Cl_2 or BCl_3. However, the electrode film **2** is not always completely removed and sometimes left behind

on the single crystalline base plate 1 owing to heterogeneous distributions of the film thickness of the electrode film 2 or reactive-ion etching rate on the surface of the single crystalline base plate 1 as shown in FIG. 1(a). A residue eliminating process called an over-etching becomes therefore inevitable in order to completely remove the electrode film 2 without leaving any residues behind. As shown in FIG. 1(b), an over-etching treatment by 5 to 50% excess of the overall etching time under a conventional etching condition is applied in the over-etching method as shown in FIG. 1(b), thereby slightly etching into the single crystalline base plate 1.

[0003]

However, the portions where the electrode film 1 has been removed and the single crystalline base plate 1 has been exposed are exposed to chlorine plasma during the over-etching time. Consequently, the single crystalline base plate 1 is damaged forming damaged layers 4 as shown in FIG. 2, thereby deteriorating characteristics of the acoustic surface wave device.

[0004]

[Problems to be Solved by the Invention]

It has been a common view that the cause of the base plate damage due to over-etching as described above is a physical damage caused by impact of ions colliding with the

base plate during the reactive-ion etching. Accordingly, the base plate damage due to ion irradiation has been suppressed by the following method of: (1) reducing the ion irradiation energy; (2) improving homogeneity of the ion etching rate; and (3) detecting the etching terminal point with high precision. However, it was impossible to completely inhibit the damage of the base plate by the conventional method, although it can be reduced.

[0005]

The object of the present invention, carried out by taking the foregoing problems into consideration, is to reduce the damages of the base plate by the reactive-ion etching during production of the electronic device.

[0006]

[Disclosure of the Invention]

The inventors of the present invention found, through collective studies, that the damage of the base plate is not simply caused by a physical damage with ions, but is caused by a chemical damage that disturbs crystallinity of the single crystalline base plate by allowing chlorine (ions, atoms, molecules or radicals of chlorine) to diffuse into the single crystalline base plate or single crystalline film.

[0007]

The electronic device according to the present invention was obtained on the basis of the facts found by

the inventors of the present invention, providing an electronic device in which a lower electrode layer comprising a material capable of reactive ion etching with a fluorine-based gas is formed on a single crystalline base plate or single crystalline film, or on a triaxial or uniaxial orientation film, an upper electrode layer comprising a material capable of reactive ion etching with a chlorine-based gas being formed on the lower electrode layer. Functional single crystalline materials such as piezoelectric substances, dielectric substances, pyroelectric substances, semiconductors and magnetic substances are used for the single crystalline base plate or single crystalline film, or for the triaxial or uniaxial orientation film depending on the kind of the electronic device. Especially when the electronic device is an acoustic surface wave device, a piezoelectric substance such as $LiTaO_3$, $LiNbO_3$, quartz, Langasite or LBO is used.

[0008]

The chlorine-based gas used for the reactive ion etching refers to a gas containing chlorine, for example a gas containing at least one of Cl_2, BCl_3, $SiCl_4$, $CClF_3$, $CHClF_2$, CCl_2F_2, $CHCl_2F$, $CHCl_3$, CCl_3F and CH_2Cl_2. On the other hand, the thin film formed on the single crystalline base plate or single crystalline film, or on the triaxial or uniaxial orientation film may be a conductive material or

semiconductor containing at least one element capable of reactive ion etching with a chlorine-based gas, example of which including at least one element among Al, Cu, Ti, Cr, Ga, As, Se, Nb, Ru, In, Sn, Sb, Ta or Au.

[0009]

The electronic device is produced by forming a substrate film comprising a material capable of reactive etching with a fluorine-based gas and a thin film comprising a material capable of reactive etching with a chlorine-based gas on the single crystalline base plate or single crystalline film, or on the triaxial or uniaxial orientation film, followed by etching the thin film by the reactive ion etching with a gas containing a chlorine-based gas, the substrate film exposed from the thin film being further subjected to the reactive ion etching with a gas containing a fluorine-based gas.

[0010]

Since the substrate film capable of reactive ion etching with the fluorine-based gas is formed under the thin film, the reactive ion etching with a gas containing the chlorine-based gas is stopped when the substrate film is completely exposed in the etching area while applying the reactive ion etching with a gas containing the chlorine-based gas. The process described above allows chemical damages of the single crystalline base plate or single

crystalline film, or of the triaxial or uniaxial orientation film with chlorine to be prevented.

[0011]

For exposing the single crystalline base plate or single crystalline film, or the triaxial or uniaxial orientation film by removing the substrate layers, the substrate exposed from the thin film by the reactive ion etching with a gas containing the chlorine-based gas is removed by the reactive ion etching with a gas containing the fluorine-based gas.

[0012]

According to the studies by the inventors of the present invention, it was made clear that crystals in the single crystalline board or single crystalline film are not subjected to chemically damages when fluorine (ions, molecules, atoms or radicals of fluorine) is used. Accordingly, the single crystalline board or single crystal film is never damaged when the exposed substrate layer is further etched by the reactive ion etching with a gas containing the fluorine-based gas to expose the single crystalline base plate or single crystalline film, or to expose the triaxial or uniaxial orientation film, making it possible to stabilize device characteristics.

[0013]

Since the damage of the base plate by the reactive ion

etching had been considered to be a physical damage in the conventional view, the same sort of damages was also considered to be caused irrespective of the kind of gases. Accordingly, it was impossible in the prior art to completely suppress the damage of the base plate, through it may be somewhat reduced. In the method according to the present invention, on the contrary, damages of the base plate by the reactive ion etching can be prevented, enabling to improve the characteristics of the electronic device.

[0014]

The substrate capable of reactive ion etching with the fluorine-based gases contains at least one element among Si, Mo, W, B, C, S and Ta with a preferable film thickness of 0.5 to 1000 nm. The substrate with a thickness of thinner than 0.5 nm may be perforated by the reactive ion etching with the chlorine-based gas while, when the thickness is larger than 1000 nm, the processing time is prolonged or the processing accuracy is decreased.

[0015]

The fluorine-based gas to be used for the reactive ion etching of the substrate may contain at least one kind of the gas among CF_4, CHF_3, F_2, NF_3, $CClF_3$, C_2F_6, $CBrF_3$, CH_2F_2, $CHClF_2$, C_3F_8, CCl_2F_2, C_4F_8, $CHCl_2F$, CBr_2F_2 and CCl_3F.

[0016]

[Description of the Embodiment]

The embodiment of the present invention will be described with reference to the attached drawings using the acoustic surface wave device as an example. As shown in FIG. 3(a), a substrate film **12** made of tungsten with a thickness of 10 nm is at first deposited by sputtering on a single crystalline $LiTaO_3$ base plate with a diameter of three inches. While the substrate film **12** is not exposed to the air (by keeping a vacuum in the sputtering apparatus), an electrode film **13** with a thickness of 100 nm consisting of Al containing 1% by weight (wt%) of Cu (referred to Al-1wt%Cu hereinafter) is deposited by sputtering on the substrate film **12** as shown in FIG. 3(b). Then, a photoresist is coated on the electrode film **13** consisting of Al-1wt%Cu, followed by forming a resist pattern **14** with a line width (L/S) of 0.5 μm and film thickness of 1 μm by forming a pattern of the photoresist by a photolithography process as shown in FIG. 3(c).

[0017]

The electrode film **13** as a lower layer of the substrate film **12** is removed by the reactive ion etching using the resist pattern **14** as a mask. The first reactive ion etching step is carried out with a parallel plate RIE apparatus using a mixed gas with a composition of (BCl_3 + Cl_2 + N_2). It is needless to say that a high density plasma source such as ICP, ECR and Helicon may be used instead of

the parallel plate RIE apparatus. An over-etching time corresponding to 30% of the overall etching time was used for the first reactive ion etching step. The electrode film **13** consisting of Al-1wt%Cu is thus dry-etched, obtaining the lower electrodes with a prescribed pattern as shown in FIG. 3(d).

[0018]

Since the etching rate of the substrate film **12** made of tungsten with the chlorine-based gas (chlorine plasma) is one tenth or less slower than the etching rate of the electrode film **13** consisting of Al-1wt%Cu, the substrate film **12** is hardly etched. Accordingly, residues of the electrode film **13** is completely removed by the sufficient over-etching treatment. Since the $LiTaO_3$ base plate **11** is not exposed at the portions where the electrode film **13** is removed, the $LiTaO_3$ base plate **11** is protected with the substrate film **12** to prevent the plate from being damaged when the reactive ion etching with a mixed gas containing the chlorine-based gas is applied.

[0019]

After completely evacuating the mixed gas of (BCl_3 + Cl_2 + N_2) from the chamber of the RIE apparatus and before exposing the $LiTaO_3$ base plate **11** to the air, it is subjected to the reactive ion etching with the fluorine-based gas to remove the substrate film **12** as shown in FIG. 3(e). The

reactive ion etching in the second step is applied with the parallel plate RIE apparatus using a mixed gas of $(CF_4 + O_2)$. The over-etching time also corresponded to 30% of the overall etching time. The substrate film **12** is thus dry-etched, giving a pattern of the lower electrode **16** with the same configuration as that of the upper electrode **15** as shown in FIG. 3(e).

[0020]

When the substrate layer **12** is removed to completely expose the $LiTaO_3$ base plate **11**, residues of the substrate layer **12** can be thoroughly removed by a sufficient over-etching treatment since the $LiTaO_3$ base plate **11** is not chemically damaged with the mixed gas with a composition of $(CF_4 + O_2)$.

[0021]

A comb-teeth shaped dual layer electrode consisting of the lower electrode **16** (tungsten) and upper electrode **15** (Al-1wt%Cu) as shown in FIG. 3(f) is obtained by washing after removing the resist pattern **14** with a resist peeling solution. This base plate (parent plate) is cut-off, assembled and wired to obtain the acoustic surface wave device.

[0022]

As hitherto described, good device characteristics can be obtained in the foregoing embodiment irrespective of

applying a sufficient over-etching treatment in the first and second reactive ion etching steps. In the conventional art, on the other hand, the base plate is chemically damaged with the chlorine plasma when subjected to an over-etching treatment of as large as 30%, resulting in severe deterioration of the device characteristics (such as insertion loss).

[Brief Description of the Drawings]

[FIG. 1] FIG. 1(a) and FIG. 1(b) denotes cross sections showing the reactive ion etching steps using a chlorine-based gas in the conventional art.

[FIG. 2] FIG. 2 shows a cross section of a base plate damaged by over-etching.

[FIG. 3] FIG. 3(a) to FIG. 3(f) denote cross sections showing the electrode forming steps according to one embodiment of the present invention.

[Reference Numerals]

12 substrate film (tungsten)

13 electrode film (Au-1wt%Cu)

14 resist pattern

15 upper electrode

16 lower electrode

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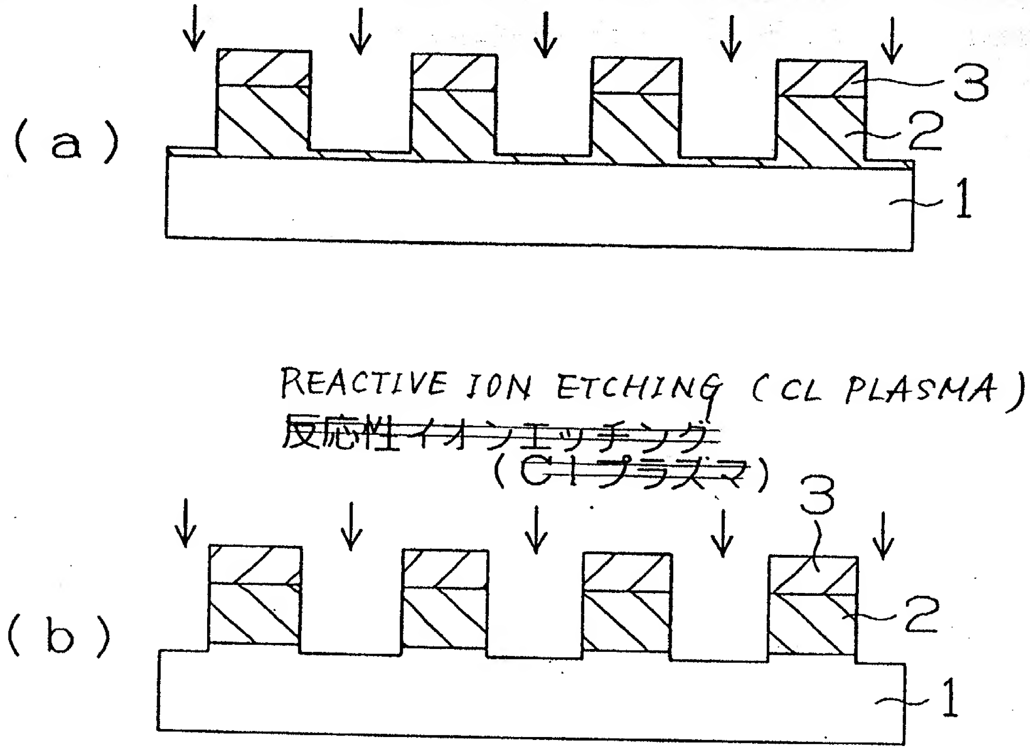
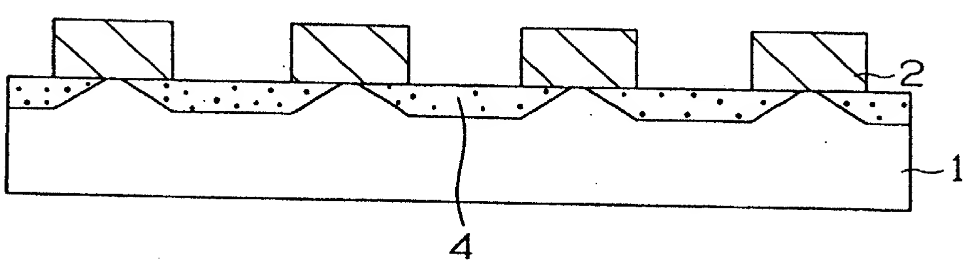
~~【書類名】~~ ~~図面~~
NAME OF DOCUMENT DRAWINGS

~~【図１】~~
FIG. 1

REACTIVE ION ETCHING (CL PLASMA)
反応性~~イオンエッチング~~
(~~Clプラズマ~~)



~~【図２】~~
FIG. 2



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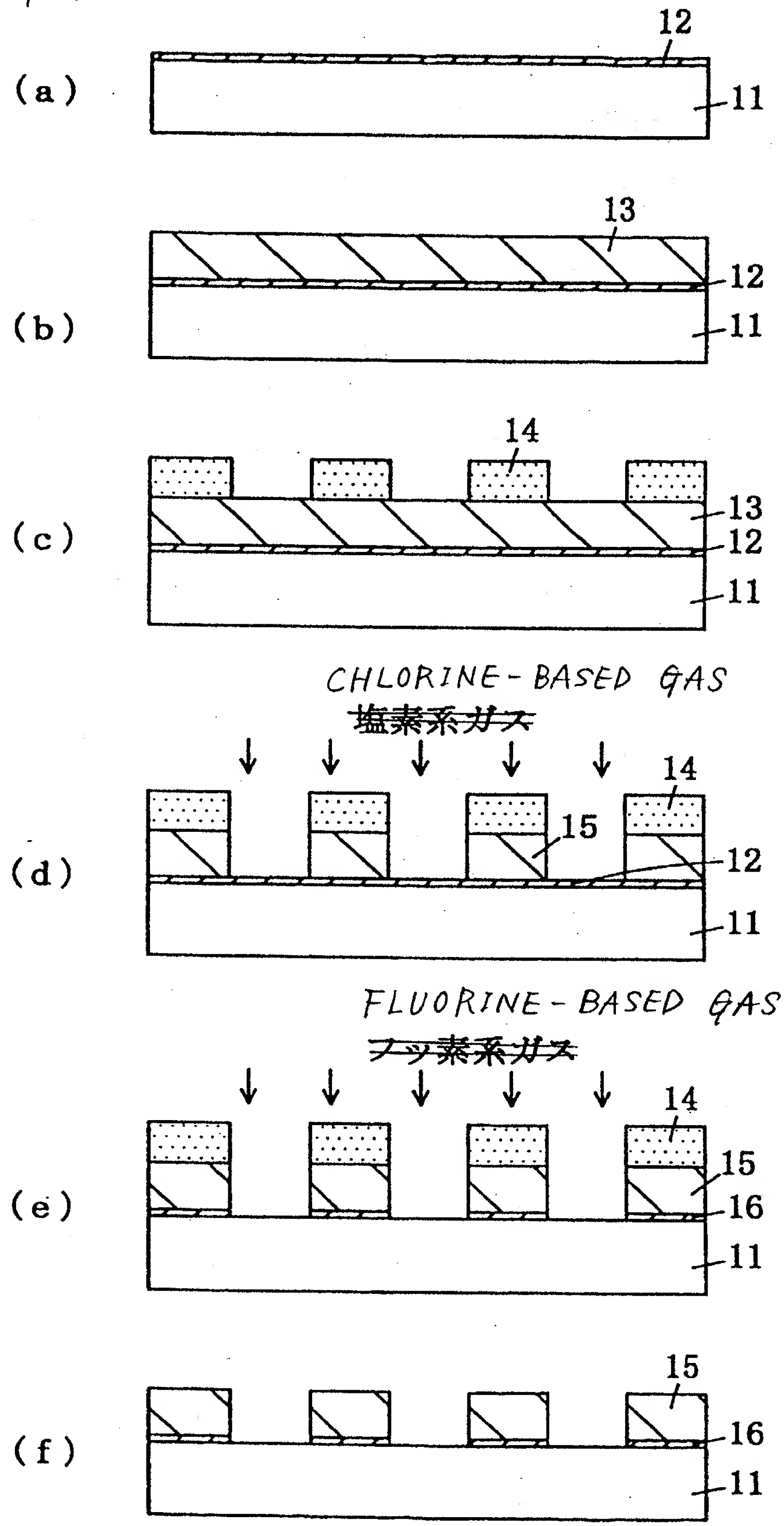
~~【図３】~~
FIG. 3



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[Name of Document] ABSTRACT

[Abstract]

[Object] The object of the present invention is to reduce damages of the base plate when the electrode patterns are formed by the reactive ion etching.

[Solving Means] A substrate film **12** made of tungsten is deposited on the $LiTaO_3$ base plate **11**, on which an electrode film **13** consisting of Al-1wt%Cu is deposited. A resist pattern **14** is formed on the electrode film **13**. The electrode film **13** is removed by the reactive ion etching with the chlorine-based gas to expose the substrate film **12**. Then, residues of the substrate film **12** are completely removed with the fluorine-based gas to expose the base plate **11**.

[Selected Figure] FIG. 3

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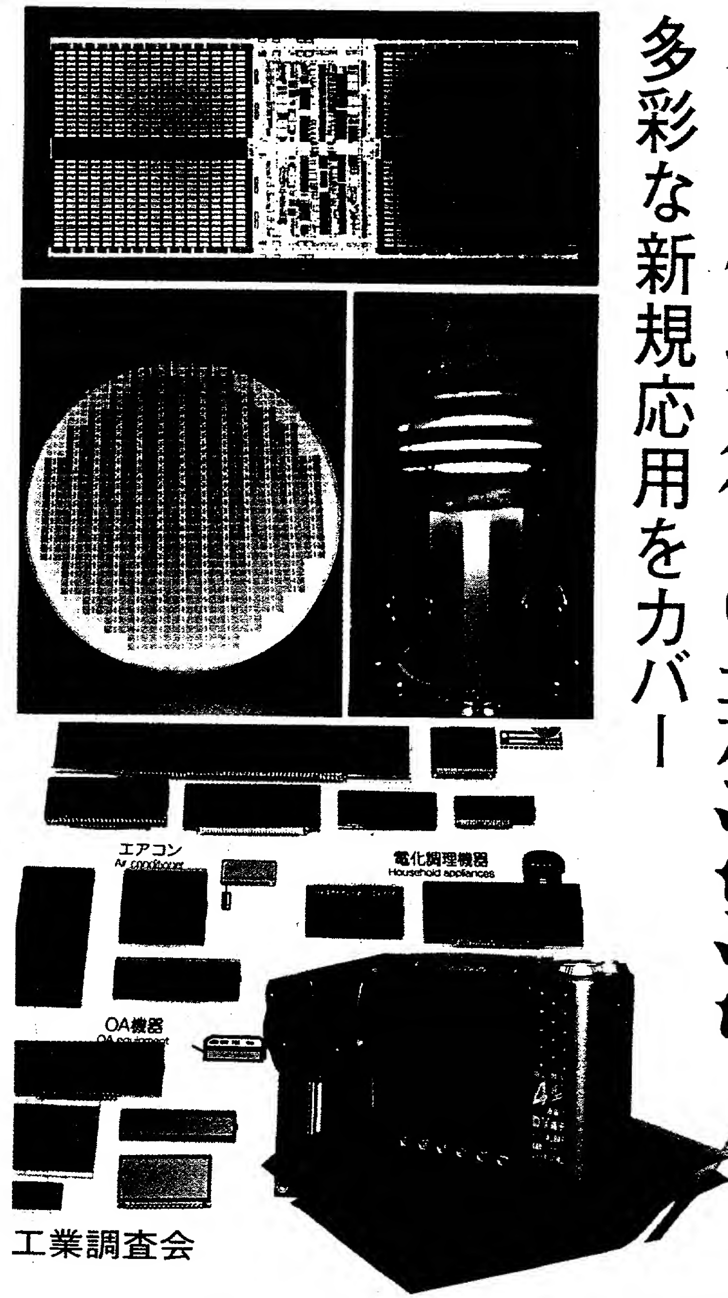

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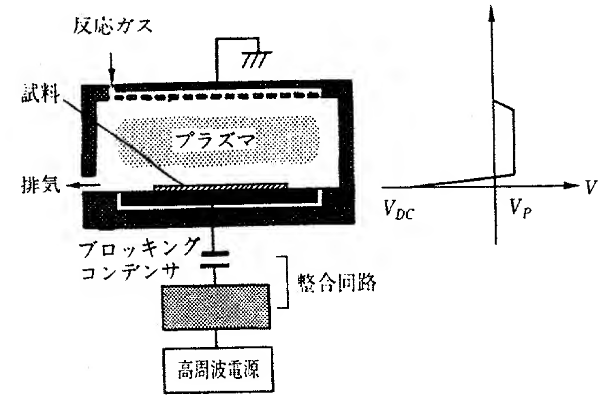

図 4.2 RIE 装置の概念図と RIE におけるプラズマの電位分布

ノード）となる。RIE ではカソード電極面積/接地電極面積≪1 とすることで，電極間に図 4.2 のようなポテンシャル分布が形成される。一般的な RIE では，動作圧力が数 Pa 程度で，カソード電極表面の自己バイアス電圧（≒イオン加速電圧）が数百 V～1kV に達する。この高周波プラズマを用いた RIE のほかに，ECR プラズマ，ヘリコン波プラズマ，誘導結合プラズマによるエッチング（本章 3.3 項）などがある。これらのエッチングは，物理的機構＋化学的機構の長所，すなわち良好な選択比，大きいエッチング速度，そしてマスクパターンに忠実なエッチング特性（異方性）を合わせもつドライエッチング方法である。

2.2 ドライエッチングガスと化学反応

表 4.2 に，各種材料に対するドライエッチングガスと化学エッチング薬液についてまとめる。ドライエッチングでは，反応ガス → 反応種（ラジカル，イオン）の生成 → 反応種の輸送 → 被エッチング材との反応 → 揮発性反応生成物の生成・脱離 → 排気，の過程で被

etching gas

表 4.2 各種材料のエッチングに用いるガスおよび薬液

	被エッチング材料 thin film	ドライエッチング		ウェットエッチング
		エッチングガス	反応生成物	薬液
Si系	Si	SF_6, CF_4, C_3F_6, NF_3	SiF_4	$HF+HNO_3$
		$CClF_3, CCl_3F_3, CCl_3F,$	$SiCl_xF_{4-x}$	KOH
		$Cl_3, SiCl_4, BCl_3, CCl_4$	$SiCl_4$	
	poly-Si	SF_6, CF_4, HBr	SiF_4	$HF+HNO_3(+CH_3COOH)$
		$CClF_3, CCl_2F_2, C_3ClF_5$	$SiCl_xF_{4-x}$	
		$Cl_3, SiCl_4, CCl_4$	$SiCl_4$	
	a-Si	CF_4, SF_6, NF_3	SiF_4	
		CCl_4	$SiCl_4$	
	SiO_2	$CF_4, CHF_3, C_2F_6, C_3F_8$	SiF_4	$HF+H_3O$, $HF+NH_4F$
		C_4F_{10}, HF		
	Si_3N_4	$CF_4, CHF_3, CH_3F_3, SF_6,$	SiF_4	$HF(+NH_4F)$，熱 H_3PO_4
		SiF_4		
	SiC	CF_4, SF_6	SiF_4	
化合物半導体	GaAs	$Cl_3, CCl_4, HCl, BCl_3,$	$GaCl_3$	
		$SiCl_4$		
		$CHClF_3$	AsF_5	
	AlGaAs	$CCl_3F_3, SiCl_4\text{-}SF_6$	(AlF_3)	
	InGaAs	$CH_4\text{-}H_3, C_3H_6\text{-}H_3$		
	InP	Cl_3, Br_3, CH_4, C_3H_6		
	ZnS	Cl_3	$ZnCl_x$	
	ZnSe	BCl_3, Cl_3	$ZnCl_x$	
金属・シリサイド	Al	$Cl_3, CCl_4, BCl_3, SiCl_4$	$AlCl_3$	$H_3PO_4+HNO_3(+CH_3COOH)$
		$HCl, CHCl_3$		
		HBr, Br_3	$AlBr_3$	
	AlSi	Cl_3, CCl_4	$AlCl_3, SiCl_4$	$H_3PO_4+HNO_3(+CH_3COOH)$
	W	CF_4	WF_6	$HF+HNO_3+CH_3COOH$
	WSi_3	$SE_6\text{-}CCl_3F_3$		$HF+HNO_3$
	Ti	CCl_4, CF_4	$TiCl_4$	希 HF
	TiN	$BCl_3\text{-}Cl_3$		$HF+HNO_3$
	$TiSi_3$	CF_4		$HF+HNO_3+CH_3COOH$
	Mo	CF_4, NF_3	MoF_6	$HF+HNO_3+CH_3COOH$
	$MoSi_3$	CCl_4, CCl_3F_3		$HF+HNO_3+CH_3COOH$

金属・シリサイド	Ta	CF_4	TaF_6	$HF+HNO_3$
	Cr	CCl_4, Cl_3		$(NH_4)_3(NO_3)_6+HNO_3$
	Pt	$CF_4, C_3Cl_3F_4, C_3Cl_3F_3$ Ar(milling)		
	Au	$CCl_3F_3, C_3Cl_3F_4$ Ar(milling)		
その他	ITO	CH_3OH-Ar		$HI+H_3PO_4, HCl+FeCl_3$
	Al_3O_3	BCl_3, CCl_4	$AlCl_3$	$H_3PO_4+HNO_3(+CH_3COOH)$
	Ta_3O_5	CF_4	TaF_6	
	PZT			$FeCl_3$

a chlorine-based gas.

エッチング材がエッチングされる。そのため，化学的機構や物理化学的機構によるドライエッチングでは，反応生成物の蒸気圧が，エッチング雰囲気の圧力よりも大きいことが必要である。

化学的機構の代表例として Si のエッチングの場合の反応過程を示す。

プラズマ中：$CF_4+e \rightarrow CF_3+F^*+e$, $CF_3+e \rightarrow CF_2+F^*+e$

基板表面　：Si(基板)$+4F^* \rightarrow SiF_4$(気体↑)

エッチングガスはプラズマ中で電子の衝撃で分解し，F ラジカルを生成する。その F ラジカルが被エッチング材の Si 表面で反応して揮発性の SiF_4 が生成され，それが脱離することによって，Si のエッチングが進行する。

実際のドライエッチングでは，以上のようなエッチング過程だけでなく，1) プラズマ中における反応で生じた生成物の基板表面への堆積や，基板表面での重合(基板表面でのポリマー堆積)，2) エッチング物質の基板への再付着，の過程も考慮する必要がある。超 LSI などで応用されている RIE では，イオンやラジカルの相対的な量の制御とともに，4) の堆積機構を利用して，エッチング速度の制御や

表 4.3 エッチング材料と反応生成物・発光種

被エッチング材料	エッチングガス	反応種	最終反応生成物	発光種
Al	$BCl_3, Cl_2, CCl_4, SiCl_4$	Cl, Cl_2	$AlCl_3$	Al (396.1nm)
SiO_2	CF_4, CHF_3, C_2F_6	CF_x, F	SiF_4, CO, CO	CO^* (483.5nm)
Si, poly-Si	SF_6, $CF_4, Cl_2, SiCl_4$, HBr	F, Cl, Cl_2, F	$SiF_4, SiCl_4$	SiF^* (777nm)
W	CF_4, SF_6	F	WF_6	F^* (704nm)
フォトレジスト	O_2, O_3	O	CO, CO_2, H_2O	CO^* (483.5nm)

異方性エッチングを実現している。

2.3 ドライエッチングにおける終点検出

微細加工を行う場合，被エッチング材料がパターン通りにエッチングできたかどうかを検出する（終点検出）ことは極めて重要である。ドライエッチングにおける終点検出は，

1) 被エッチング材料の膜厚・屈折率の変化（エリプソメトリ，レーザ干渉などの光学測定）
2) 分解・反応生成物の種類・量の変化（質量分析，ガスクロマトグラフ，プラズマの発光測定，吸光測定）
3) プラズマの状態の変化（探針法，放電インピーダンス測定）

などを検知することによって行う。

この中で比較的簡易で高感度であるため，現在 RIE で一般的に用いられているものが，プラズマの発光測定による終点検出である。エッチングプラズマの発光スペクトルは，エッチングガスとその分解生成物や反応生成物などのラジカルやイオンからの発光の総和である。**表 4.3** にエッチング材料と反応生成物についてまとめてある。

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検印廃止

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